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The concept of Polycentrism in Infrastructure networks An application to airports

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Abstract

This paper applies the concept of inter-regional polycentrism, which is commonly used in territorial development and strategic planning, to the airport networks design. Authors aim to demonstrate that airlines would be able to offer more direct connections if airports were to function in an inter-regional polycentric logic instead of in a monocentric logic on a national scale. Inter-regional polycentric logic is related with a multiplicity of strong autonomous poles. Monocentric logic is related with poles without critical mass in a hierarchical structure where one strong pole is dominant. In the specific case of air transport infrastructures, Spanish airports currently function in a monocentric network in relation to the capital (Madrid), and this is why the peripheral Galician airports considered in this study have neither the critical mass nor accessibility to enable them to function as independent/autonomous poles. This means that if the Galician Region would be served by fewer airports, each of them could have a greater critical mass, becoming then a stronger pole. Being stronger poles, Galician airports wouldn't be so dependent of Madrid and that would allow them to guarantee a greater accessibility. This is what inter-regional polycentrism aims: the co-existence of strong poles with an integrated and balanced development.
Using mathematical simulation with current air transport connections, authors attempted to understand what could happen if the undifferentiated airports of the Iberian Peninsula area would have sufficient critical mass to guarantee greater accessibility on an international scale.

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Keywords: airport networks; polycentrism; infrastructures planning.

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1. The concept of polycentrism

The concept of polycentrism as applied to territory is defined as "the existence of more than one centre in a city, region or other territorial unit" (Musterd and Zelm, 2001). The polycentric territorial model arose as a response to the collapse of the monocentric model in the understanding of territorial structuring. This transition is definitive and irreversible, as the monocentric model – the exact opposite of the polycentric model – is no longer appropriate for interpretation and understanding of the spatial patterns of North America, Europe and Japan, even where adaptations of the monocentric model have been attempted *(Kloosterman, 2001)*.

The decline of the monocentric model and subsequent rise of polycentrism can be essentially attributed to the phenomena of decentralization and restructuration *(Clark and Kuijpers-Linde, 1994)*. Decentralization is a result of the flexibility provided by increased mobility, while restructuration is strongly associated to economic restructuring, with changes in production methods and economic specialization, which have fundamental repercussions on the localization of workplaces. Decentralization of economic activities, growing individual mobility and lifestyle changes have led to transformation in the way urban areas are organized. Other authors further attribute the emergence of polycentrism to an increase in motorization (Musterd and Zelm (2001), profound changes in communication technology *(Bourdeau-Lepage and Huriot, 2005)*, multiple displacement patterns, fragmentation of spatial distribution of activities and changes in family structure and lifestyle *(Davoudi, 2003)*. Although there are no universally accepted justifications for the emergence of polycentrism to the detriment of monocentrism, it is generally accepted that the disappearance of the structure with a dominant centre around which activities took place, and the emergence of a multiplicity of poles linked by various relationships and networks, is set to change the dynamics of territorial organization. The end of the monocentric model contributed to a change in the nature of relationships between agglomerations: hierarchical relationships inevitably persist but they are, however, no longer dominant. Horizontal relationships based on a mixture of cooperation and competition now proliferate; the degree of specialization is no longer as linearly dependent on the size of the agglomeration and does not depend merely on the immediate surrounding area but also on international perspective. Since its emergence, the concept of polycentrism has been applied on different spatial scales. On a European scale, intra-urban, inter-urban *(Kloosterman, 2001)* and inter-regional economic and populational concentration patterns can be cited *(Davoudi, 2003)*, *(ESDP, 1999)*, *(Dieleman and Faludi, 1998)*. Intra-urban polycentrism is associated with a more reduced spatial territory, that of the metropolitan area, while inter-urban polycentrism manifests itself within entire regions. Inter-regional polycentrism is emerging in the EU and its manifestation involves a system made up of polycentric regions. This type of polycentrism is widespread in northeastern Europe and was originally put forward in the *European Spatial Development Perspective* (ESDP). This document proposes functional polycentrism promoting complementarities between European urban areas in such a way as to create more balanced territories with critical mass and good economic performance. The development of a polycentric urban system in Europe involves the existence of a set of poles with infrastructural connections between them, and the presence of functional links between cities in order to establish complementarities and cooperation *(Richardson and Jensen, 2000)*. 'Accessibility', therefore, is a key factor for the development of polycentric systems.

In this context, the authors chose the North Region of Portugal and the Region of Galicia in Spain to use as a case study for the application of the concept inter-regional polycentrism. These regions share a similar civic culture, strong flows of interaction and possess the specific characteristics of polycentric configurations *(Kloosterman, 2001)*, namely: they have historically distinct cities; there is not one single city which is clearly more important in political, cultural, economic or other terms (although inevitably one of the cities will have a greater number of inhabitants); there are a small number of medium sized towns which do not differ greatly in size or economic importance, linked with smaller towns, and the towns involved in this configuration are all relatively close together. They differ spatially and have independent political identities. Adopting the concept of polycentrism as the "multiplicity of *centers which are independent* of leadership, power or ideology and which exist in a single system, with a view to their integrated and balanced development" *(Costa et al, 2005)*, in this paper authors adopted a concept clearly linked to regional structuration and transpose it into transport

infrastructures. It is not intended to present a detailed description of the concept of inter-regional polycentrism but solely to explore its application to transport networks. Polycentric networks can be useful in reducing costs and congestion, and in promoting territorial equity by means of sustained development of various network centers *(Costa et al, 2005)*, which do not have sufficient critical mass to perform well as individual centers. In the specific case of air transport infrastructures, it will be noted that the Spanish airports function in a monocentric network in relation to the capital (Madrid), and this is why the peripheral Spanish airports considered in this study have neither the critical mass nor accessibility to enable them to function as independent/autonomous poles. These peripheral airports and the Portuguese North Region airport could be a structural part of inter-regional polycentrism, if the Spanish infrastructures would have satisfactory levels of critical mass and accessibility.

2. Geographical and socio-economic scope

The case study presented in this paper refers to the Northwest of the Iberian Peninsula, covering the North Region of Portugal and the Region of Galicia in Spain (Figure 1). In terms of the territorial model, the Galician urban system differs considerably from that of the Portuguese North Region. The Galician Region has a network of seven towns polarized along the coast, whereas the Portuguese Region consists of a consolidated conurbation called Grande Porto (Facal, 2000). Galicia has two areas of greater urban concentration: Coruña-Ferrol with around 330,000 inhabitants and Vigo-Pontevedra with more than 360,000 inhabitants; the conurbation of Grande Porto in the North Region of Portugal has a population of around 1,200,000 distributed in a more widespread form around the territory. Although these differences on territorial structures, Galicia and the North Region of Portugal present some similarities in terms of social and economic structure (Table 1). The Portuguese North Region has a population of 3,687,293 inhabitants distributed over 21,280km2 and a population density of 173 inhabitants/km2. This value is significantly greater than that which is registered in Galicia, where there are 92 inhabitants/km2 – a population of 2,732,926 distributed over an area of 29,574 km2. In terms of effective populational dynamic, Galicia had a population growth of less than 1% between 1991 and 2001 while the Portuguese North Region grew by 6.2%, a fact which have contributed over the past decade to accentuate the difference in populational density between the two territories (INE, 2005) (INE, 2005). In 2001, the activity rates of both regions had similar values: 48.1% for the Northern Region and 49.5% for Galicia. The active population is distributed similarly across economic activity sectors. Agriculture was responsible for 12% of the active population in the Northern Region and 14% in Galicia. With regard to industry and the service industry, there are some differences: in 2002, 42% of the active population of the Northern Region was employed in industry whereas this was the case for only 33% of the Galician population, while in the service industry the figures were 46% for the Portuguese region and 53% for the Spanish region. In terms of unemployment rates, figures for the two regions differed significantly in 2001, with a rate of 6.7% being registered in the Northern Region and 10.6% in Galicia. In spite of these figures, the GDP per capita of Galicia is 12,800 euros, a higher figure than that of the Northern Region which registered a value of 9,600 euros (INE, 2005) (INE, 2005).

3. Case study

In the Northwest of the Iberian Peninsula there are 4 main air transport infrastructures: Porto, Vigo, Santiago and Coruña airports. Porto Airport is located in the Portuguese North Region and the other three airports are located in the Region of Galicia in Spain (Figure 2). Portuguese airports are managed by ANA, Aeroportos de Portugal, which is responsible for administrating 9 airports (3 in continental Portugal and 4 in the Azores islands, plus 2 in Madeira by it's participated company ANAM, Aeroportos e Navegação Aérea da Madeira). Until 2012, ANA was a public company with its own legal and financial independent status. Recently, ANA was sold to VINCI group, which now has a 40-year concession to operate the Portuguese Airports. Spanish airports are managed by AENA (Aeropuertos Españoles y Navegación Aérea) which is responsible for administrating 47 airports and one heliport, is a public company with its own legal personality and independent of the Spanish state.

The traffic volume registered in the mentioned airports varies significantly, as can be seen below in Table 2. Located 11 km from Porto, Porto airport has a single runway, an area of 320 ha and has recently undergone major improvements that have increased its capacity to 6 million passengers. This airport has lately been targeted by low-cost carriers, namely Ryanair and Air Berlin, which have been providing daily connections, and this has resulted in the increase in passenger volume. After a period of decrease in passenger numbers (between 2000 and 2002) at an annual rate of 11.6 %, the volume of passengers in Porto has been growing over the last decade, particularly since 2007 due to the growth induced by Ryanair.

Table 2 demonstrates the clear importance of Porto Airport in the Northwest of the Iberian Peninsula; it is the largest airport in terms of passenger movement with approximately the double of the amount of passengers of the three main airports in Galicia. Its location, the large area of influence covering a territory which is relatively urbanized and therefore with enormous market potential, together with excellent road accessibility, make this infrastructure a crucial node in the transport network of the Portuguese North Region and indeed of the whole of the Northwest of the Iberian Peninsula. Santiago Airport is used for both civil and military purposes, being built upon land of which ownership is shared between AENA and the Ministry of Defense, and is located 10 km from Santiago de Compostela, the cultural capital of Galicia. Santiago Airport owes a large part of its activity to tourism, given that the city served by this airport is the largest tourist attraction centre in Galicia, with hotels and rural guesthouses registering more than 3,800,000 tourists in 2004 (GIT, 2005). Vigo Airport has a 2400 m runway and a 7500 m2 terminal, and is located 9 km from the city of Vigo, the most important business area of Galicia. Located 8 km from the city of Coruña, Coruña Airport has capacity for 12 flights per hour. Vigo and Coruña airports, whose traffic movements are smaller than the previously mentioned airports, have an eminently regional character, with national flights accounting for a significant share on the total traffic. Between 2001 and 2007, the three Galician airports (altogether) had more traffic than Porto Airport. Since 2007 Porto experienced a fast growth rate, mostly to “Ryanair effect”, and now has more than 6 MPax against 3.8 MPax of all the Galician Airports, which have been losing traffic over the recent years.

However, with regard to airport strategy the difference between Portugal and Spain is notorious: continental Portugal has 3 airports for a total population of approximately 10 million inhabitants (1 airport per 3.3 million inhabitants), while continental Spain has 34 airports for a population of around 38 million (1 airport per million inhabitants). This difference in the proportioning of airport infrastructures could explain the differences in traffic volume registered in the airports of the two transborder regions (see Table 1). Besides the significant difference in terms of critical mass which affects each of the analyzed airports, it is worth to show the differences in terms of destinations. The most relevant variables which determine the choice of an airport by a passenger are flight frequency, air fares and accessibility (Caves and Gosling, 1999). In order to evaluate the number of destinations provided by each airport, a survey of departures was carried out using real-time information on the ANA and AENA websites. The authors collected data in different days of the week, once fares vary according with the day of the week and authors wanted to have a reliable sample of the period. The use of real time information is due to the difference between the flights that actually took place and those that were programmed. Nevertheless, a similar analysis should be made for the winter schedule and for other periods and months in order to overcome the influence of seasonal patterns and to validate these results. Concentration indices were calculated from real-time information on the ANA and AENA websites (ANA, 2005) (AENA, 2005), which allowed us to determine the eventual dominance of particular destinations at the respective airports. The purpose of the concentration index, is to demonstrate whether an airport is highly dependent on a certain airport.

The concentration indices are calculated according to formula [1].

$$C_j = \frac{\sum_{i=1}^{j} n_i}{\sum_{i} n_i} \times 100 \qquad [1]$$

where n_i represents the number of daily connections registered for destination i, with destinations being placed in decreasing order of connections (n_1 - number of connections for the most popular destination, n_2 - number of connections for the second most popular destination, and so on) and c_j represents the concentration index j. Therefore, c_1 shows the percentage of connections to the most popular destination, c_2 the percentage of connections to the two most served destinations, and so on. If an airport has a c1 of 100%, it means it only serves one airport. Lower the ci, means less dependency on specific airports, thus a more wide market served. The results show that Porto Airport has the lowest dependence on other airports: its primary destination (Paris) represents just 16% of daily connections. Coruña Airport shows the greatest dependence: it has only 4 destinations, with 81% of its connections destined for Madrid and Barcelona. Vigo and Santiago airports also have more concentrated destinations than Porto and with a smaller number of international connections (Table 3). These values make clear the difference in terms of destinations offered by the 4 airports and, in particular, of the importance of domestic connections at the Galician airports. It could even be said that these airports function as 'feeders' for the hubs of Madrid and Barcelona, feeding the Iberia network which provides the great majority of connections to these airports, directly or via Vueling. In fact, Table 4 suggests that the 'feeding role' is played by Vueling. The situation of excessive integration into the Iberia network is risky for the Galician airports, and particularly for their customers: on one hand, the absence of competition leads to higher prices (see Table 4) and on the other hand, as Iberia is a Full Service Carrier, with a network logic centered in a large hub (Madrid), connections from Galicia to Europe are routed via Madrid and, as a consequence, the number of stopovers in a journey is increased and the choice of carrier is conditioned. It is also interesting to transpose territorial models and concepts to the transport models. In territorial terms there is a monocentric model in relation to Madrid, and in terms of transport infrastructure there is a hub and spoke logic to the Iberia network, also based in Madrid, and which has a large share of the critical mass of the strongest centre in Spain. The current Spanish airport network, clearly reinforcing the hub and spoke design, influences the development of secondary airports (with regard to number of passengers and number of connections), in this specific case of the Galician airports. This contrasts with the case of Porto Airport which has multiple daily direct connections to Paris, London, Frankfurt, Madrid, Barcelona and Lisbon, giving its customers the possibility of flying with Air France, Lufthansa, British Airways, TAP and Iberia among other companies. This situation contributes to an increase in competition and destinations on offer, as well as a reduction in fares. In territorial terms, this international accessibility means that Porto Airport is a stronger pole than the Spanish ones analyzed on this paper.

Porto Airport currently serves, on a regular basis, 61 destinations, while Santiago, Coruna and Vigo, offer 27, 6 an 4, respectively. The difference in destinations services is obvious, with Porto accounting almost twice the number of destinations combined of the 3 Galician airports. In order to assess the effect of Galician airport policy on flight prices, fares for 5 destinations were gathered. Three European destinations to large cities with hubs were chosen (Paris, London and Frankfurt), one to North America (Toronto) and one to South America (where Iberia - Spanish flag carrier - has a strong presence). The fares presented in Table 4 were obtained for flights on the 7th May 2013 and were collected every week, starting six weeks away from departure, to avoid particular situations like a peak of demand for a flight on a certain day. Since fares vary according to the hour of the day, it was chosen to look at the fares on different days at the same hour everyday. In this particular case, the authors opted for collecting data between 12:00 and 12:20 everyday in order to get comparable data. Authors could have chosen other period of the day to extract fares as long as after they make their choice, they would collect data everyday on that predetermined period. The criteria for reservations were, first direct flights and second the cheapest flight available. The italic number refers to the number of stopovers between origin and destination.

The data from Table 4 shows the existence of a competitive atmosphere at Porto Airport, a result of the presence of several companies leading to lower fares. Even flying with Iberia or Air Europe to Caracas, the Porto departure is cheaper than any of those from Galician airports. Once again, the dependence of these airports with relation to the Madrid hub can be clearly seen. The airport planning system adopted by AENA has a structure

similar to a hub and spoke network, with several small airports around one main airport. In the case of the Galician peripheral airports, this structure creates a situation of near monopoly on Spanish airlines, which results on fewer international flights and at higher fares.

4. Conclusions

The main decision-making processes concerning investment in transport still have to contend with market forces which promote centralization, and are based more on national policy than European policies which promote radial and concentric models around the national capitals (Azevedo and Cichowlaz, 2003). The implementation of inter-regional polycentrism is not assured only by political will. Relationships between poles are necessary, and these will not be created without context and a common will. In the case of the Northern Region and the Region of Galicia, there are factors which bring these regions together and minimize the existence of a national border. These geographical, climatic, social and cultural factors can be fundamentals for the promotion of complementary and competitive relationships between the regions. Despite the strong political, economic and territorial constraints that such solution would face in practice, both regions would benefit from this model. However, the authors are aware that it is very difficult to follow an inter-regional polycentric logic in airports planning, particularly in cases which require closing airports. As it also happens with territorial models, changing from a national monocentric model of airport's network to an inter-regional polycentric one would in turn contribute to a change in the nature of the relationships between airports. There would still be a hierarchical relationship between Madrid and the Galician airports, but it would be less significant. Horizontal relationships would be promoted, based on a mixture of cooperation and competition, and the Galician Region would become integrated into the international scope. The existence of a single airport in Galicia, thereby centralizing the critical mass of the region, would create a stronger pole, which would be more independent of the central pole in Madrid. This increase in critical mass would bring benefits for the Northwest of the Iberian Peninsula, namely reduced fares, greater international accessibility and less dependence on stronger poles.

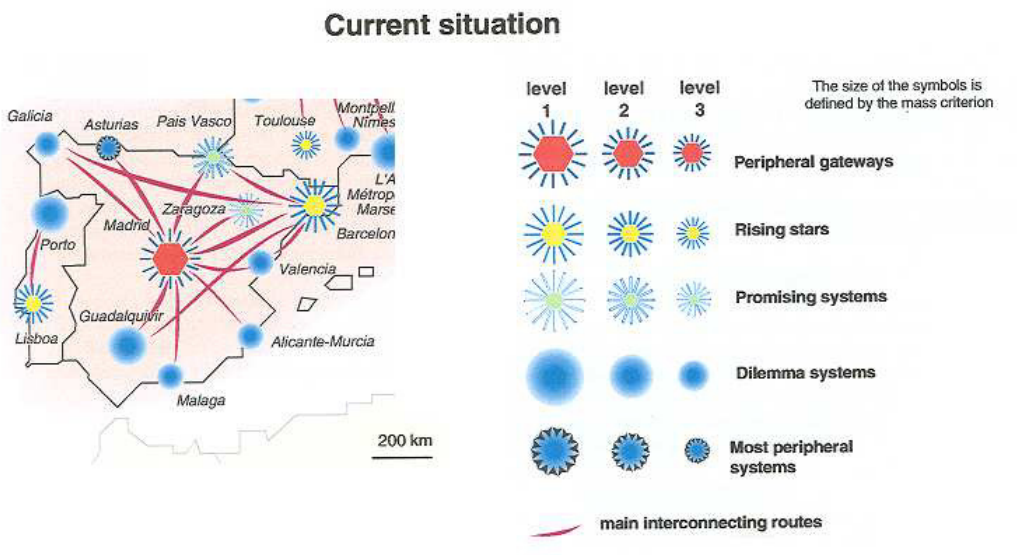

Fig. 1. Polycentrism in Portugal and Spain

Source: adapted from (ESDP, 1999)

Fig. 2. Location of the main airports of the Northwest of the Iberian Peninsula

Table. 1. Social and Economic Structure

	North Region (Portugal)	Galicia (Spain)
Population (inhabitants)	3 687 293	2 732 926
Area (km^2)	21 280	29 574
Population Density (inhabitants/ km^2)	173	92
Population Growth (1991/2001)	6.2%	< 1%
Activity Rate (%)	48.1	49.5
Agriculture Active Population (%)	12	14
Industry Active Population (%)	42	33
Services Active Population (%)	46	53
Unemployment Rate (%)	6.7	10.6
GDP/capita (euros)	9 600	12 800

Table. 2. Evolution of passenger traffic in the Northwest Iberian airports

	Santiago	Vigo	Coruña	Total Galicia	Porto	Total Northwest Iberian
1999	1399267	621488	492642	**2513397**	2832722	**5346119**
2000	1334550	721608	589000	**2645158**	2938118	**5583276**
2001	1281334	790540	654092	**2725966**	2771169	**5497135**
2002	1240730	778861	532298	**2551889**	2633380	**5185269**
2003	1381826	840013	549871	**2771710**	2675753	**5447463**
2004	1580494	911975	586243	**3078712**	2944135	**6022847**
2005	1843118	1108720	852322	**3804160**	3108186	**6912346**
2006	1994519	1188046	1014839	**4197404**	3402816	**7600220**
2007	2050172	1405968	1266795	**4722935**	3986515	**8709450**
2008	1917466	1278762	1174970	**4371198**	4535813	**8907011**
2009	1944068	1103285	1068823	**4116176**	4509350	**8625526**
2010	2172869	1093576	1101208	**4367653**	5283361	**9651014**
2011	2464330	976152	1012800	**4453282**	6004589	**10457871**
2012	2194611	828720	845452	**3868783**	6051048	**9919831**

Table. 3. Airport concentration indices by destination

	Santiago	Vigo	Coruña	Porto
c1	28% (Madrid)	62% Madrid)	60% (Madrid)	16% (Paris)
c2	45% (+Barcelona)	77% (+Barcelona)	80% (+Barcelona)	29% (+Lisbon)
c3	56% (+Palma)	92% (+Paris)	90% (+London)	42% (+Madrid)
c4	62% (+Malaga)	100% (+Bilbao)	100% (+Sevile)	49% (+London)
c5	68% (+Tenerife)	-	93% (Lisbon)	56% (+Barcelona)
c6	74% (+Alicante)	-	94% (+Gran Canaria)	61% (+Frankfurt)

Table. 4. Fares for different destinations from the airports in this study

	Paris	London	Frankfurt	Toronto	Caracas
Porto	**182.19** *0* Ryanair	**71.48** *0* Ryanair	**156.52** *0* Lufthansa	**839.08** *1* Lufthansa	**715.14** *1* TAP
Santiago	**508.43** *1* Iberia	**277.37** *0* Vueling	**457.73** *1* Iberia	**836.17** *2* American Airlines	**845.95** *1* Air Europa
Vigo	**418.92** *1* Vueling	**253.83** *1* Vueling	**485.97** *1* Iberia	**2402.84** *1* Air France	**842.28** *1* Air Europa
La Coruna	**385.10** *1* Vueling	**175.48** *1* Vueling	**429.93** *1* Iberia	**810.45** *2* American Airlines	**896.56** *1* Iberia

Note:

Fare
Number of stopovers
Airline

These fares were randomly selected, and concern a fight on the 7th of May.

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